1wf

NASA TECHNICAL TRANSLATION NASA TT F-14,282

DYNAMIC TESTING OF HELICOPTER COMPONENTS

H. Schumacher, Eng.

Translation of: "Dynamische Erprobung von Hubschrauberkomponenten", Betriebsfestigkeitsprobleme bei Hubschraubern, (Helicopter Fatigue Testing), Deutsche Gesellschaft fuer Luft- und Raumfahrt, Stuttgart (West Germany), (Proceedings of the DGLR Symposium on Helicopters and Propellers, Immenstaad, West. Ger., 24 Jun 1969), December 1970, pp 97-123

(NASA-TT-F-14282) DYNAMIC TESTING OF HELICOPTER COMPONENTS H. Schumacher (Techtran Corp.) May 1972 29 p CSCL 01B

N72-28000

Unclas
G3/02 30418

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546 JUNE 1972

30

TABLE OF CONTENTS

NASA TT F - 12,282

DYNAMIC TESTING OF HELICOPTER COMPONENTS

H. Schumacher, Eng.

ABSTRACT: Initially the importance of dynamic component testing for the development of helicopters is presented. Using the the development of the BO 105 as an example, the test planning and execution used demonstrate the multiplicity and range of the test purposes. Various tests are presented in a series of figures for clarification.

/98*

1. Introduction

Importance of Dynamic Component Testing

In developing helicopters knowledge of the permissible dynamic stresses of the components plays a very special role.

No other flying machine has as great a multiplicity of dynamic components, the reliability of which is of such critical importance, as the helicopter. Its dynamic systems are subject directly to an alternation of stresses, of which the frequencies and amplitudes are mainly determined by the main and tail rotor revolutions, their harmonics and their opposing interference.

For example, the stress occurring with the fifth harmonic is not to be disregarded in connection with a rotor blade. With a more or less corresponding service life of components, this leads to load cycles which can extend into the area of 10^8 and more.

The consequence is that tests are to be made to determine the permissible stresses up to such load cycles. This is especially true of materials for which no definite fatigue limit has yet been established, such as plastics reinforced with fiberglass, but also in general whenever a stress includes fretting corrosion, erosion, aging produced by weathering or similar processes.

* Numbers in the margin indicate pagination in the foreign text.

The following processes play a significant role in connection with helicopter components: fretting corrosion with all bolt connections, flange connections or bearing sites; erosion with rotor blades; aging of plastic parts by weather. /99

2. Test Planning

As a result of the special importance of the processes mentioned above, it is necessary to simulate the most real load conditions in test planning with the most complete components or component groups possible, with special attention being paid to attaching these parts as in the original. An attachment which is reinforced differently from the original has different fretting corrosion relationships, a different stress course within the attached area and different tolerances when different materials are joined. This last statement is also true of chemical, electrolytic and similar influences.

Therefore it is often necessary, in order to acquire the necessary knowledge, to carry out various kinds of tests with one and the same component, e.g., one time the dynamic strength and another time the most favorable bearing relations (kind of bearing, manufacture of ring bearings, etc.) of a component are to be determined while still other tests can occur as a third test for the purpose of considering a special process analytically. The latter happens, e.g., in the form of fretting tests with GFK and titanium tests to investigate various surface treatments.

The test sequence presented in the following sections can be used to apply the test results to the real situations:

2.1 Small Specimen Tests

With materials having unknown ultimate stress values, fatigue tests with various load ranges and different mean stress allotments are carried out to determine these basic values. For instance, the specimens for GFK research are cut out of complete rotor blades in order to eliminate any final treatment /100 deviations and thus to determine the real ultimate stress values. These specimens are cheap, so that a sufficient number of test statements about distribution are also possible. These tests can be carried out with commercial pulsators.

2.2 Individual Component Tests

In order to measure the dynamic strength under high operating stresses, fatigue tests with various load increments or multistage tests can be carried out. Here it is necessary to use tighter clamps or to make opposing components built as dummies tighter than in the original in order to be sure of fractures in the components to be investigated. These tests can be carried out partially with commercial pulsators, and partially with specially produced testing machines, if the magnitude of the experimental procedure or the stress simulation make this appear more favorable.

2.3 Component Group Tests

Single stage or multistage tests under slightly increased operating loads are used to determine real operating behavior. Here in every case original restraint conditions are presumed, guaranteed by using the original components with their real interaction. Normally specially developed testing machines are used for these tests.

2.4 System Tests

We shall not go any deeper into this matter here. Let it merely be noted that only the functional interaction of the components in a system test provide /101 the final information about the usefulness of the components before the actual flight tests.

With a non-articulated rotor, as achieved in the BO 105, favorable control characteristics of the helicopter are achieved by rigid blade restraint. Naturally this improvement, compared to standard rotors with articulated blade attachments, results in a considerable change in power and moment distribution. The novelty of the system caused us to check out all the dynamic components dynamically, too. Even when the material for the prototypes was being manufactured, care was taken to prepare numbers of corresponding pieces of the components for fracture tests. Before definite testing on components as installed in the helicopter, developmental tests took place to determine the shape of the components. In particular in the following figures various examples of component tests are presented, with more details being paid to the test techniques than to the test results.

It should also be noted that we extract as much information as possible from every test, everything which is available and for which modern measuring technology provides any possibilities. Thus normally, during the entire length of the test, forces, moments, stresses, deformations and temperatures are measured, if possible on the specimen itself, in order to become familiar with all interdependencies, and these are monitored so that when any set limit is exceeded the machines automatically shut off.

3. Test Performance /102

The first figures (1-3) show tests on small GFK specimens to determine their bending strength in alternating bending tests and in tests on bend swelling. Here and in the following tests (1-5) we are dealing with specimens cut cut of rotor blades: rectangular Roving specimens (Figure 1), nose pieces of fabric and Roving with a lead insert (Figure 2), and trailing edge pieces of fabric and foam (Figure 3). Hairline fractures and fabric rips occur as breaks in the tensile stressed zone and gradually extend into the inside of the specimen.

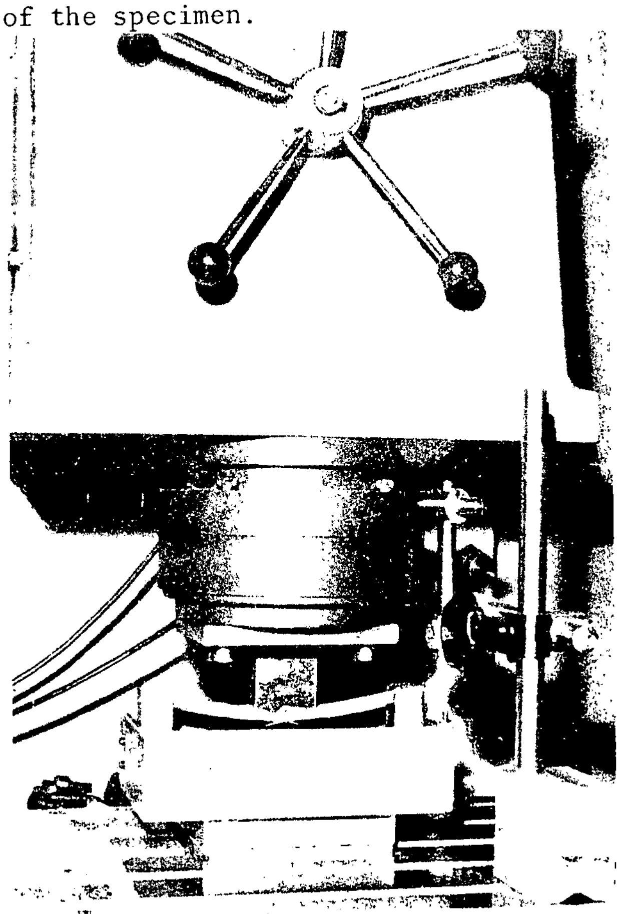
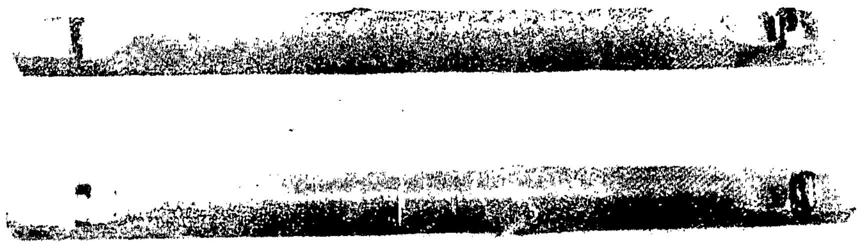


Figure 1.



/103

Figure 2.

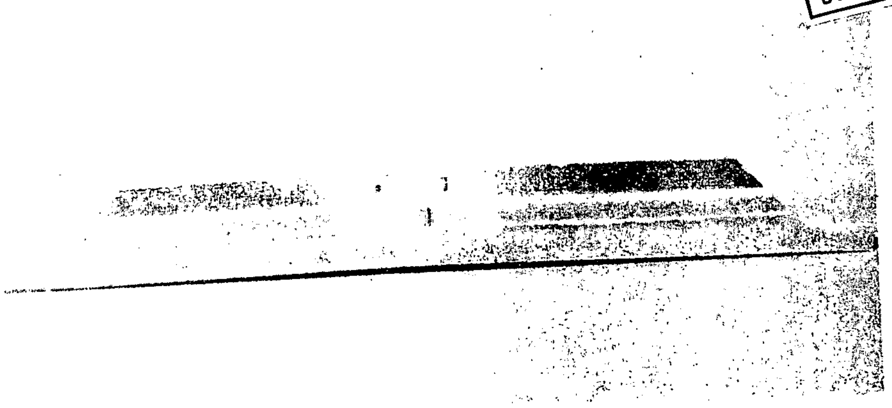


Figure 3.

Since the load is maintained constant, an increasing deformation amplitude corresponding to the damage occurs, and this is measured by a displacement pick-up throughout the test.

Likewise the temperature increase to be observed while the damage extends is recorded. Here a commercial 2 to-Resonance pulsator made by the Schenck Company is used as a testing machine.

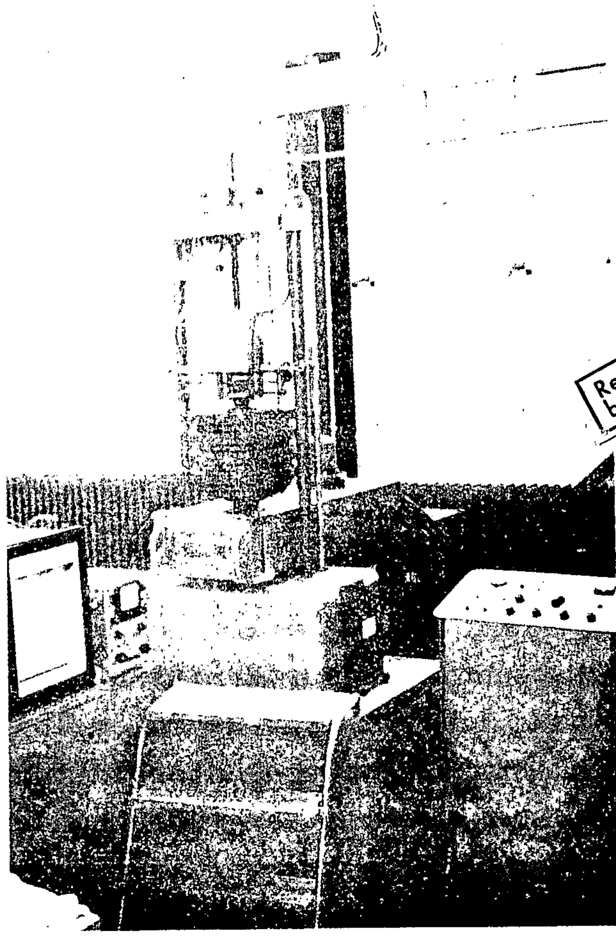


Figure 4.

Further tests on GFK specimens, this time to determine the shear strength in the bend swelling tests, are shown in Figures 4 and 5. Here the σ/τ ratio is equal to 8, as opposed to 50 in the previous test, so that the shear strength limits are reached here for the first time. At failure delamination occurs in the middle of the specimen. With this stress arrangement the effects of testing temperature, artificial aging and various other parameters are also determined. The pulsator is a resonance pulsator manufactured by the Amsler Company with a Brabender tempering chamber. /104

Figure 6 shows tests with rotor blade sections to determine the dynamic torsional strength. These are segments 60 cm long taken from the homogeneous transverse area of the rotor blades. The torsion moment is kept constant and the increase in deformation amplitude and the stress in the blade are measured by means of a wire strain gauge. Cross shaped rips 45° to the axis appear as fractures. The testing machine used is 6 to-Resonance pulsator from the Schenck company.

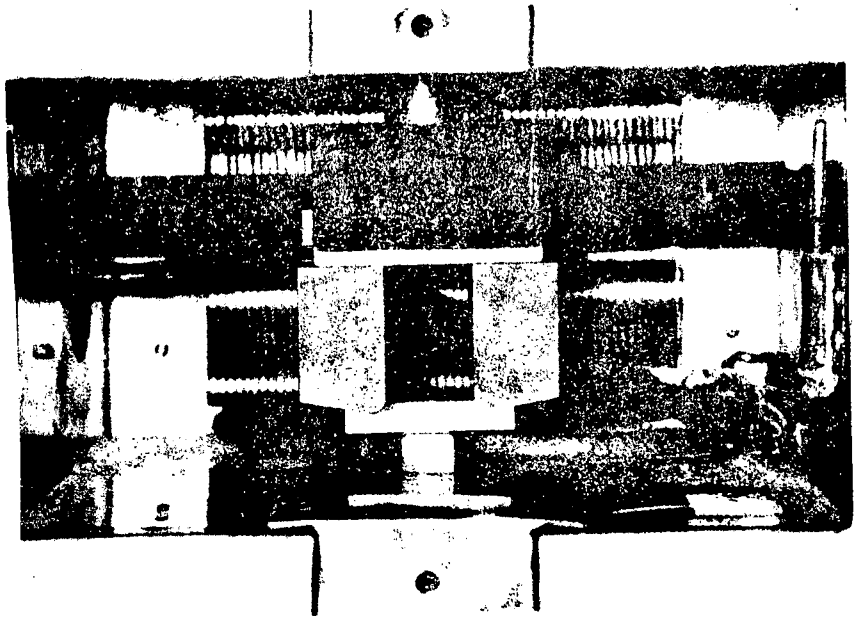


Figure 5.

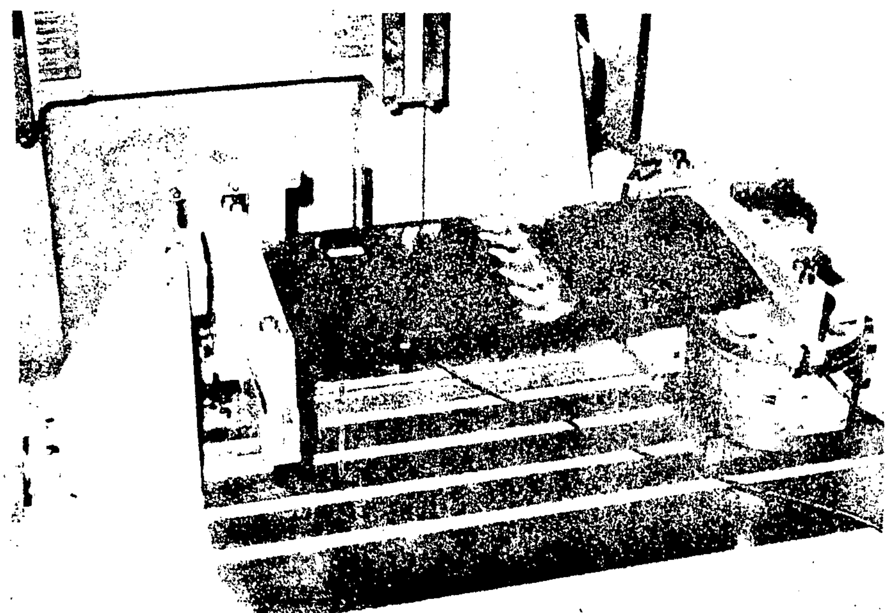


Figure 6.

Abrasion tests made with a specially built testing machine can be seen in Figures 7 and 8; with these GFK specimens and titanium specimens with different surface conditions are moved back and forth in a constant deformation path and with constant frequency below a constant normal force and the abrasion behavior is evaluated. /105

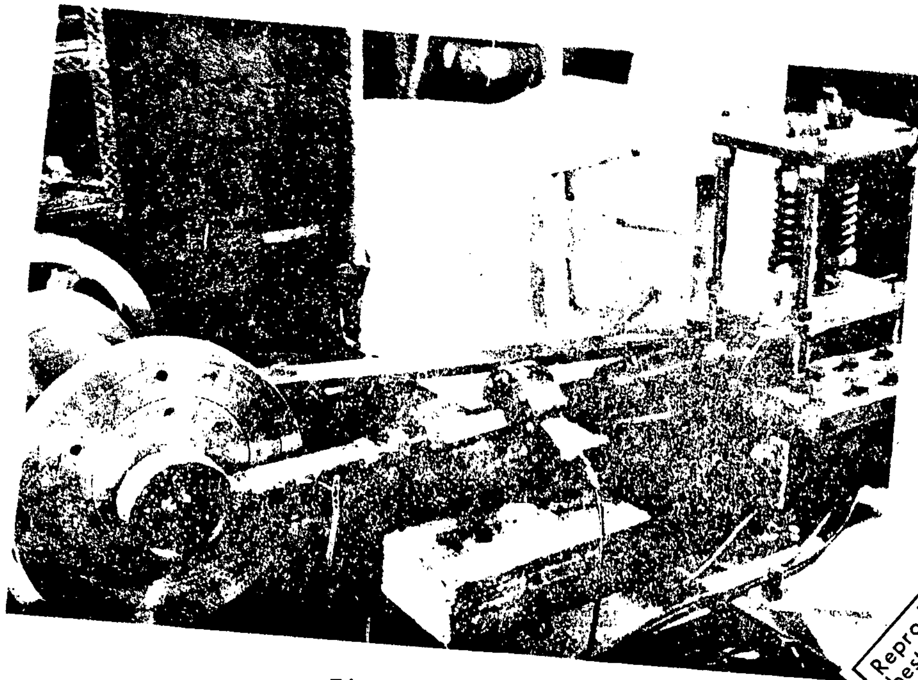
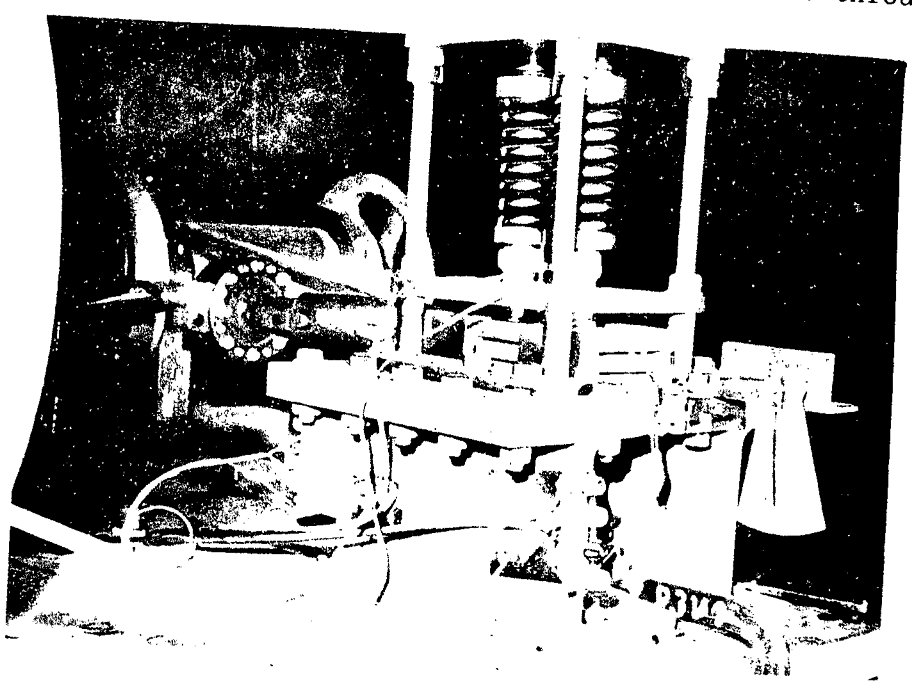


Figure 7.

These tests are intended to simulate the abrasion between the GFK blade grommet and the metal coating under bending stress. Normal force, abrasion force, abrasion path and temperature are measured and recorded throughout the testing.



/106

Figure 8.

Two blade bending machines developed and built by us are presented in Figures 9-11. They are used to load the main rotor blades, particularly the root area with the original plating, and partially the original blade retention fork. The longitudinal force is applied hydraulically with the cable and cup springs. Impact bending and fluctuation bending stresses are produced by 2 eccentrics, which can be adjusted independently and can be adjusted in their phase relationship. Forces and moments are maintained constant during the test, while the stresses and temperatures in the blade are measured and monitored.

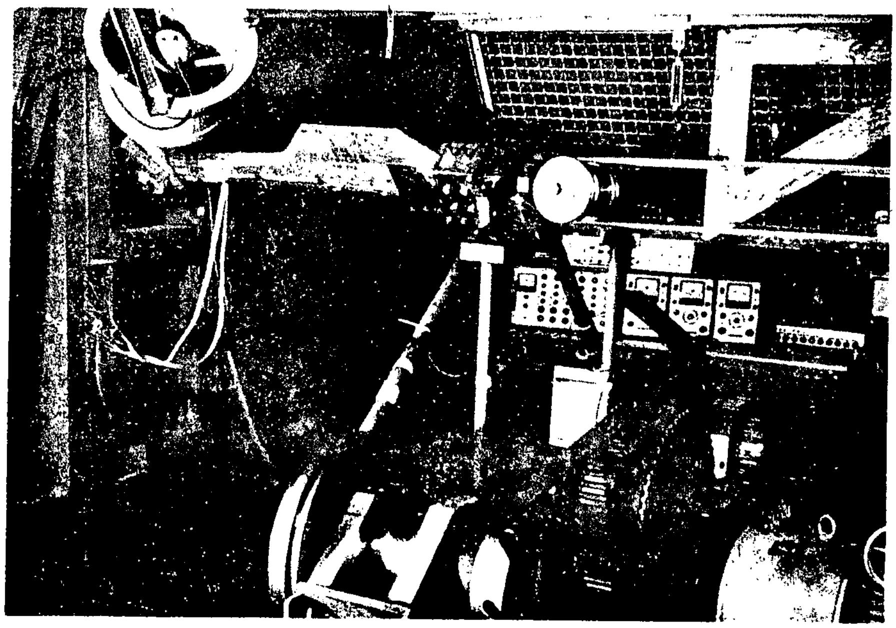


Figure 9.

/107

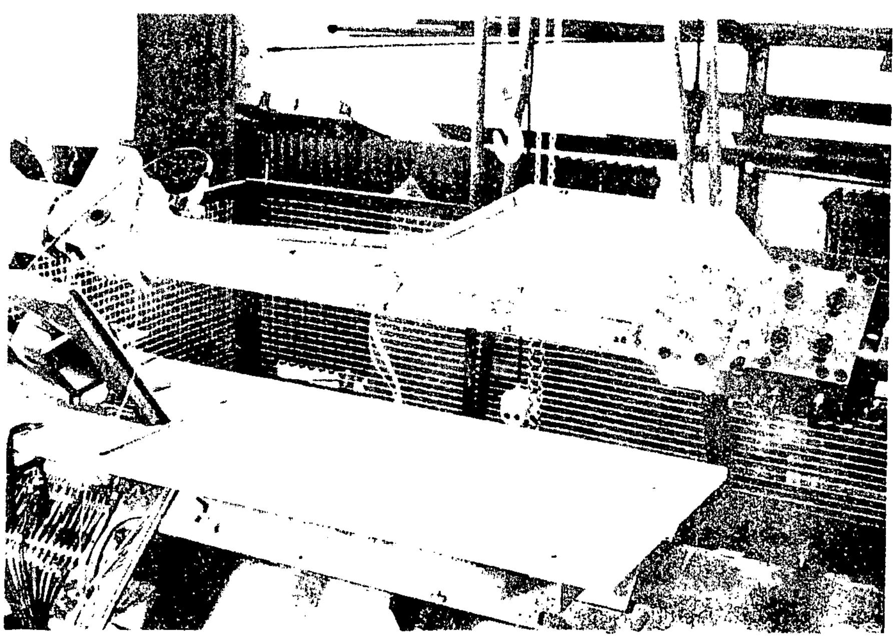


Figure 10.

If the established limiting values are not met or are exceeded, the machine automatically shuts off. High temperature tests can also be run in machine number 1. A tempering chamber with heat blown in, produced by us, serves this purpose.

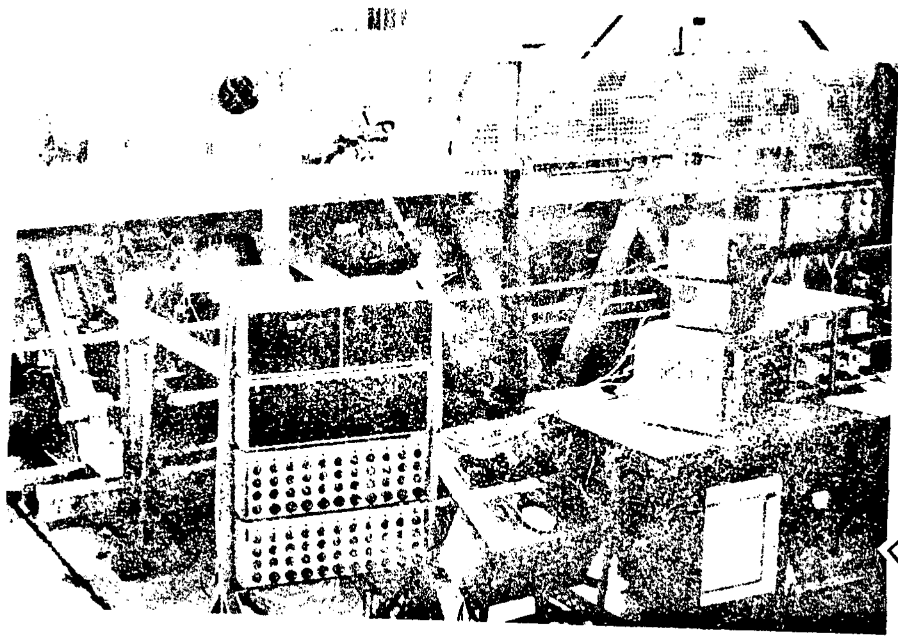


Figure 11.

In Figures 12 and 13 the transition region of a main rotor blade from the root to the homogeneous section, the so-called throat, is loaded in a testing machine which was also built by us. /108

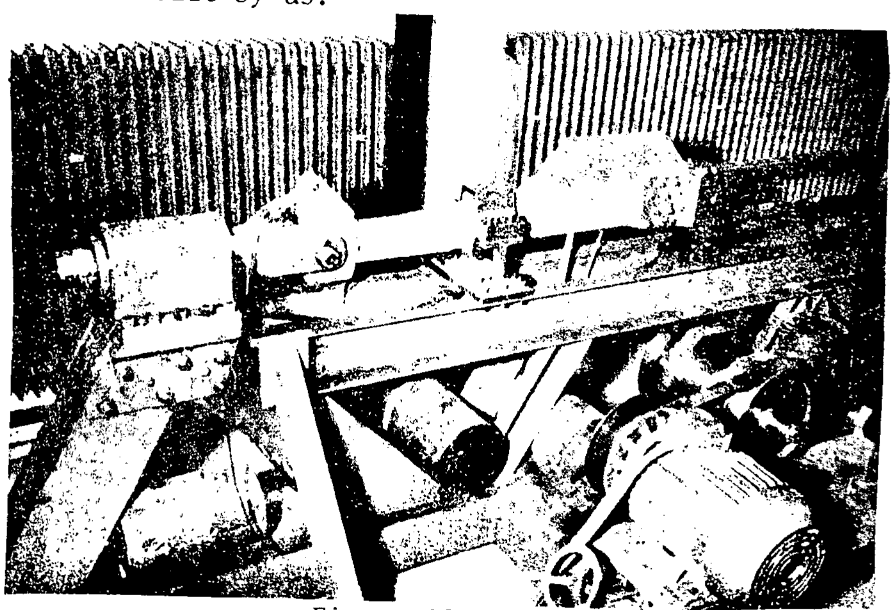


Figure 12.

Loading proceeds as above, but here the stress is limited to the direction of repeated bending. The fractures which occur lie in the throat region.

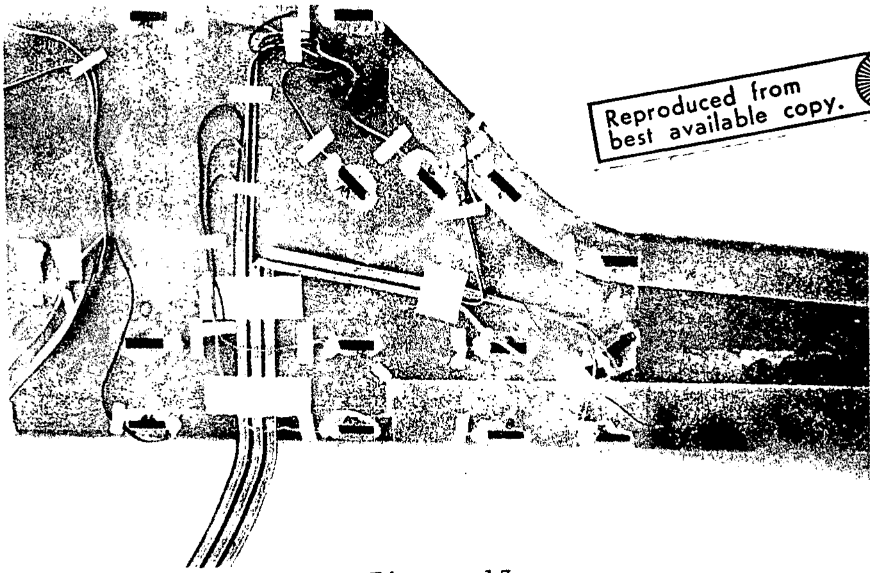


Figure 13.

Load is produced in the impact and bending direction of a GFK tail rotor /109
blade (Figure 14) by turning the blade with its chord in an oblique plane, so that the impact bending and oscillation bending overlap to the desired extent. A control lever prevents the blade from escaping the desired load direction, which is prescribed by an eccentric.

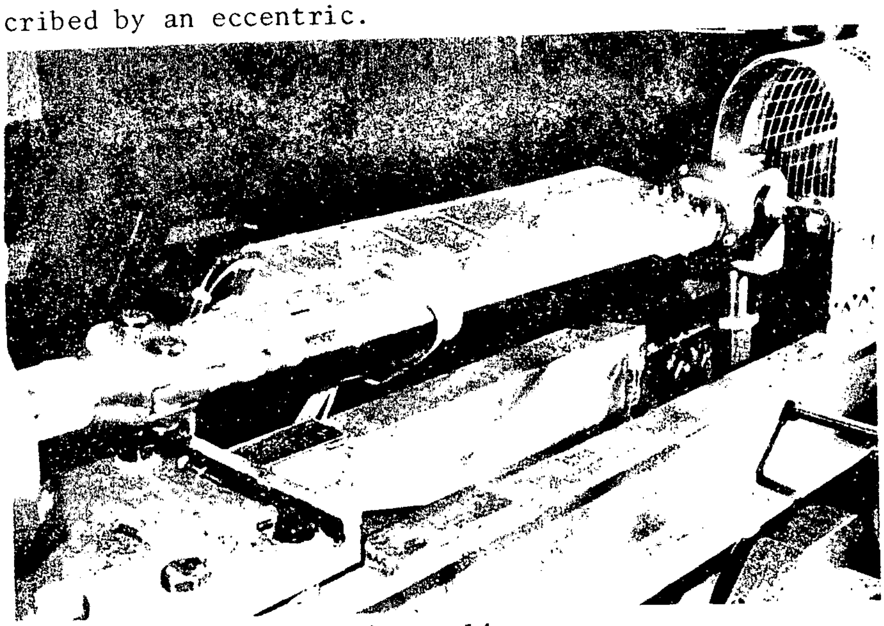


Figure 14.

For similarly loading the tail rotor blade attachement of the BO 105, a power controlled pneumatic cylinder is used, as shown in Figure 15. The electronic control and regulation system keeps the applied load constant, and this is our own development.

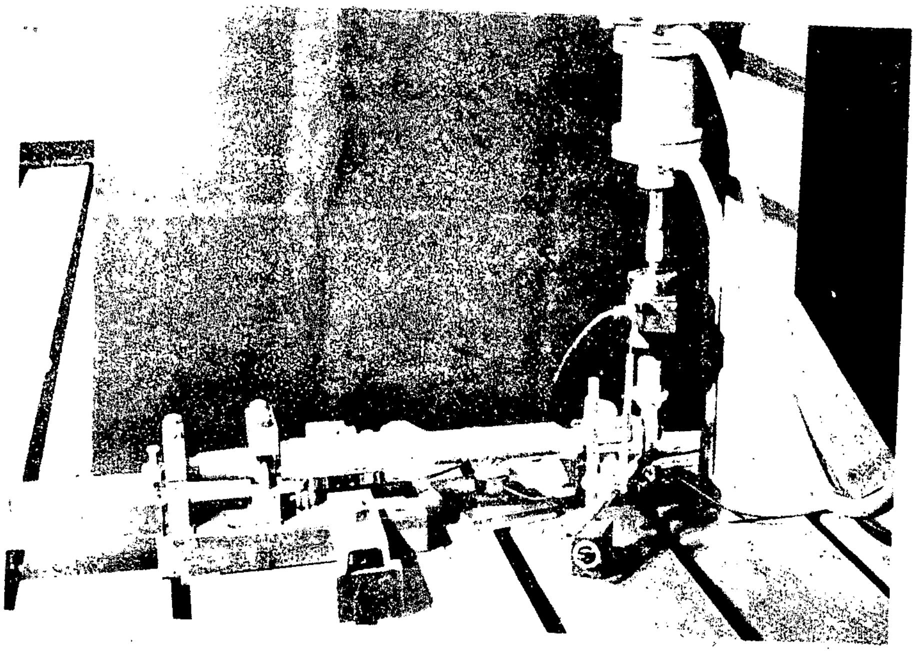


Figure 15.

Further tests took place with the homogeneous region of a main rotor blade (Figure 16 and 17). In a testing machine produced by us the blade is incited to an oscillation bending with 2 joints. The blade is elastically suspended in 1 joint. In the vicinity of the other joint vibration is caused by an eccentric and a free-hanging operating rod. /110

In this way very high amplitudes (up to ± 250 mm with a blade 3 meters long) can be produced, as are necessary to reach the fatigue strength of the GFK. These testing arrangements make it possible to avoid large applications of force at one point with their resulting sudden shear forces which would otherwise affect the test results.

Figures 18-20 show the investigation of Bendix joints, torsion flexible elements which are used in the BO 105 to increase the flight power of the blades, but which give only slight resistance to blade shifting caused by slight torsion rigidity and thus bring about only small blade control forces. /111

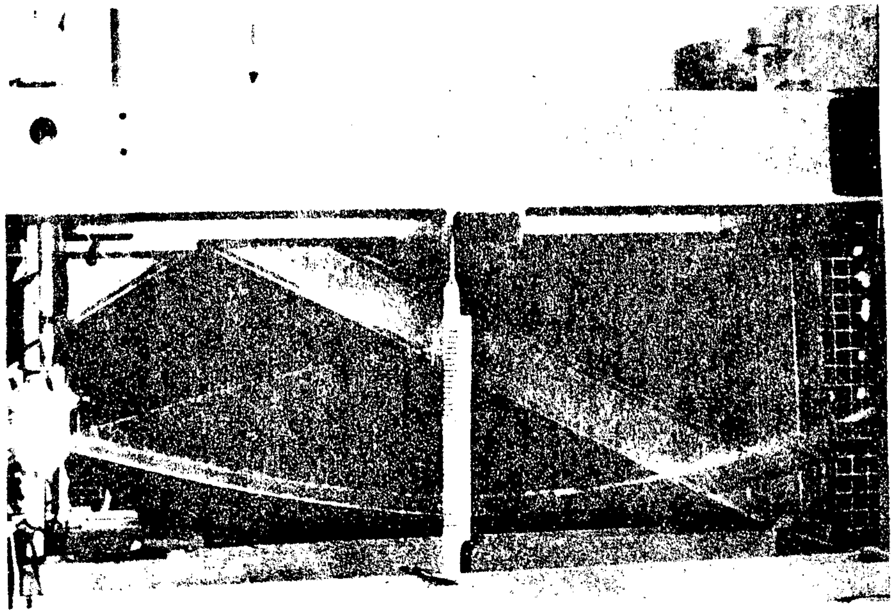


Figure 16.

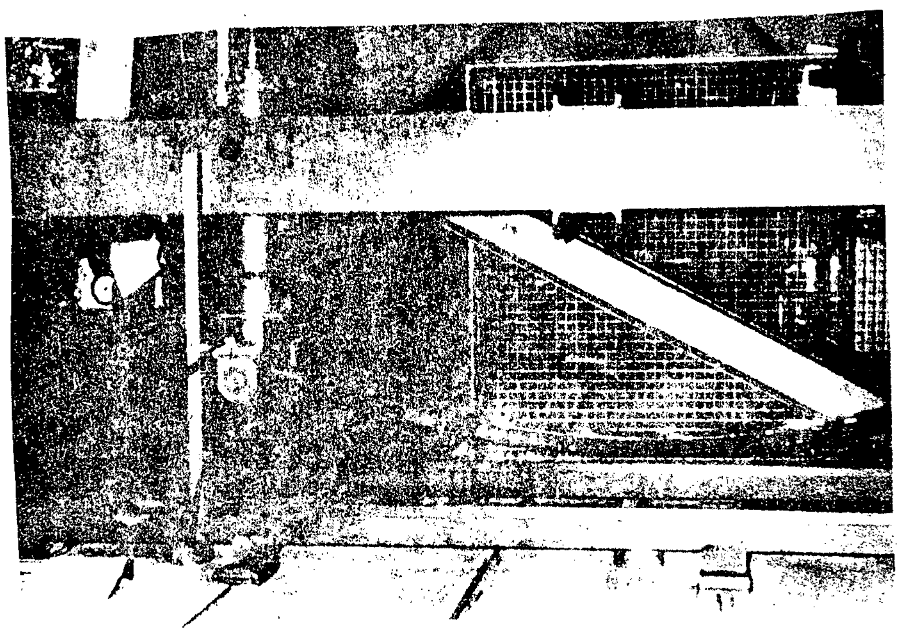


Figure 17.

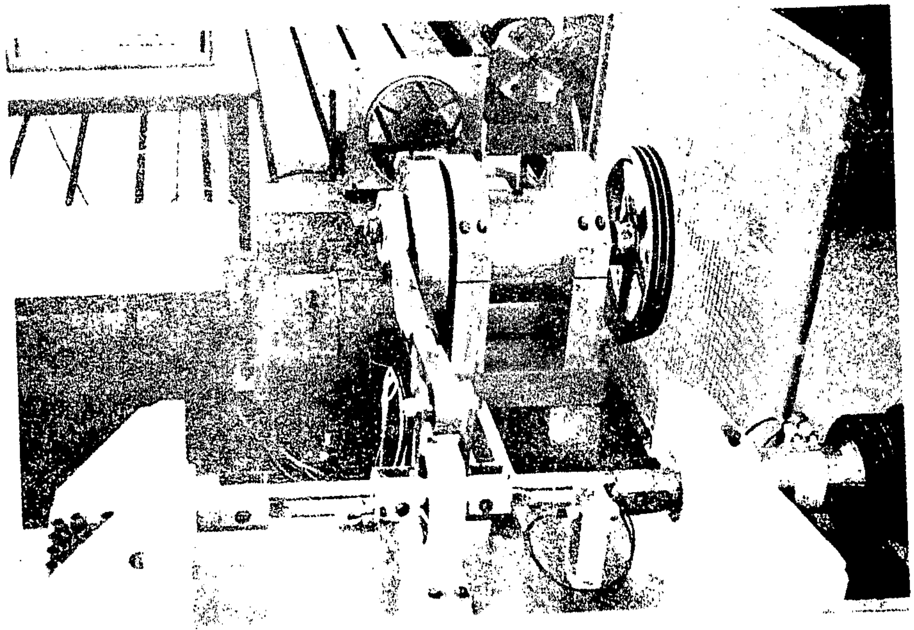


Figure 18.

Figure 19.

These elements are twisted cyclically in a machine (Figures 18 and 19) under longitudinal force to the fatigue point and loaded in another machine (Figure 20) with an increasing tensile load to simulate the starting and running of the rotor. Machines built by us are used here. /112

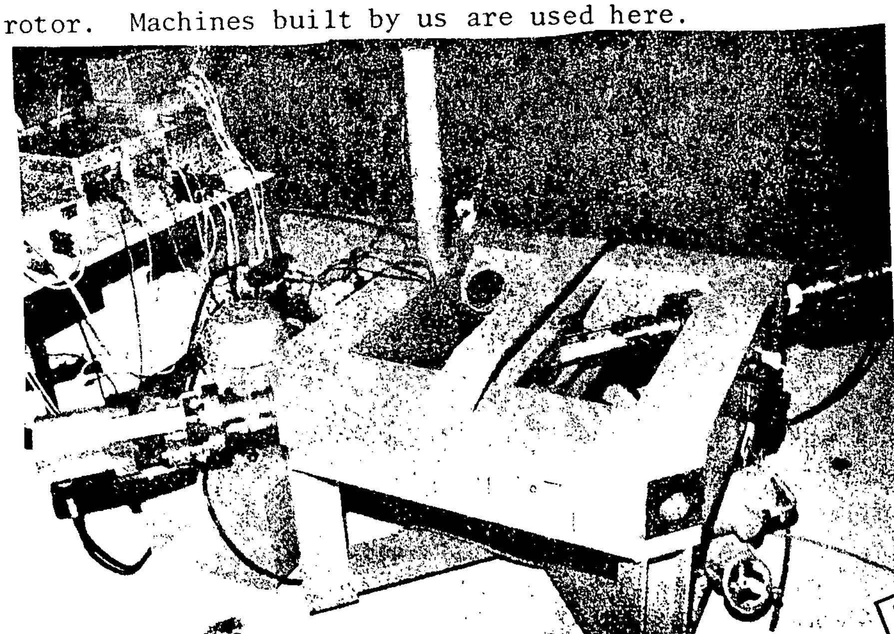


Figure 20.

As can be seen in Figures 21-25, the main rotor head of the BO 105 is made of titanium alloy. This head, also called hub, is loaded with 2 or even 4 hydraulic cylinders on its arms.

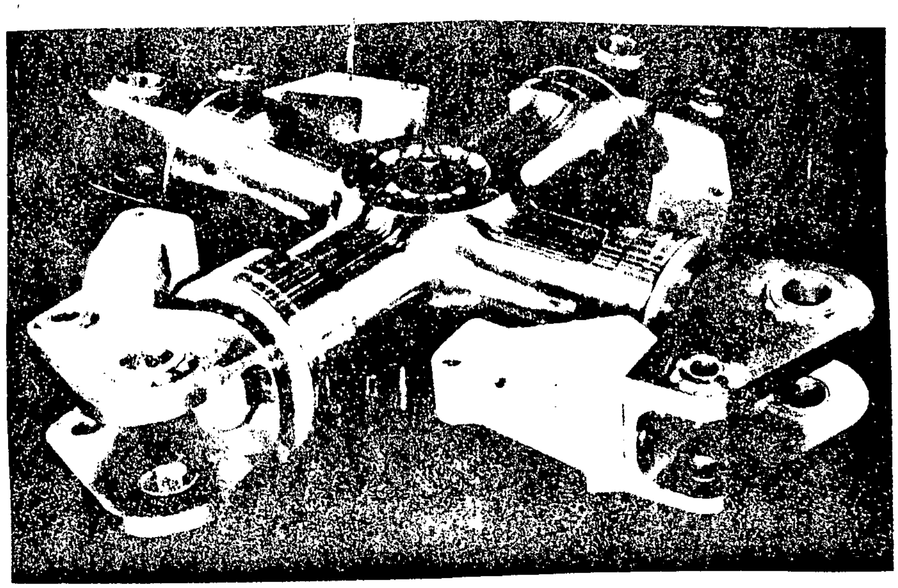


Figure 21.

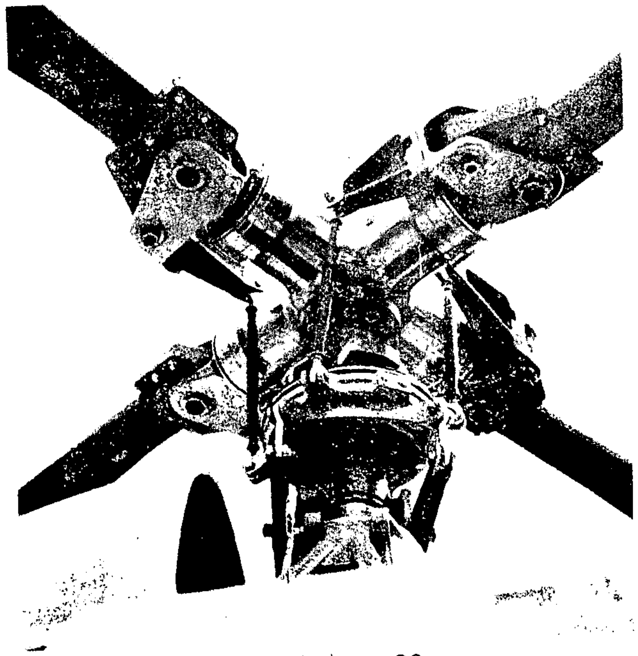


Figure 22.

Massive metal rods inserted in the arms of the head, are used as load accessories; in this case the normally present tin bearings in the head are replaced by DU bushings. The hub is flanged along the flange side by an original rotor wave dummy and screwed tightly to a tension field. The hydraulic cylinders simulate a rotory bending load in such a way that their loads are out of phase by 90° each. In this way single stage and multistage tests are carried out. The direction of force of the cylinders is chosen in such a way that the bending moments achieved in the impact and vibrating direction are of the same magnitude.

The loading of the BO 105 blade retention casing, also made of titanium alloy, is shown in Figures 26 and 27. This casing is mounted in an adapter which represents one arm of the hub, and a metal adapter is inserted into its fork instead of the rotor blade (Figure 26 b). The specimen is broken at the eyes by bending loading in a machine (Figure 26 a), and in this case the pin bearings normally located in the arm are replaced by DU bushings. In the second machine (Figure 27) the pin bearings are tested specially, with the bending load corresponding approximately to the maximum operating load and with the rotation of the bearing during bending being superimposed so that the rotational velocity is at its greatest with the maximum bending load. /115

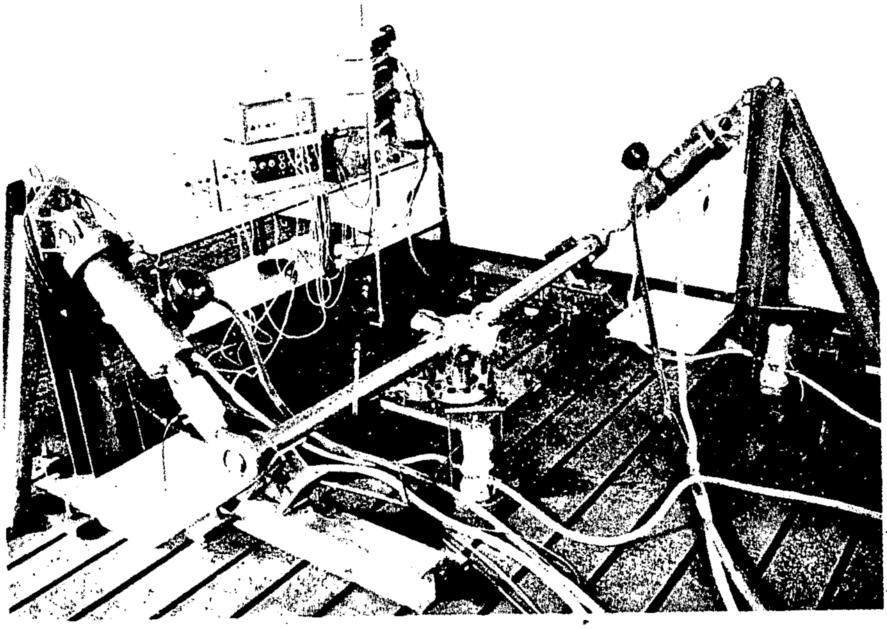


Figure 23.

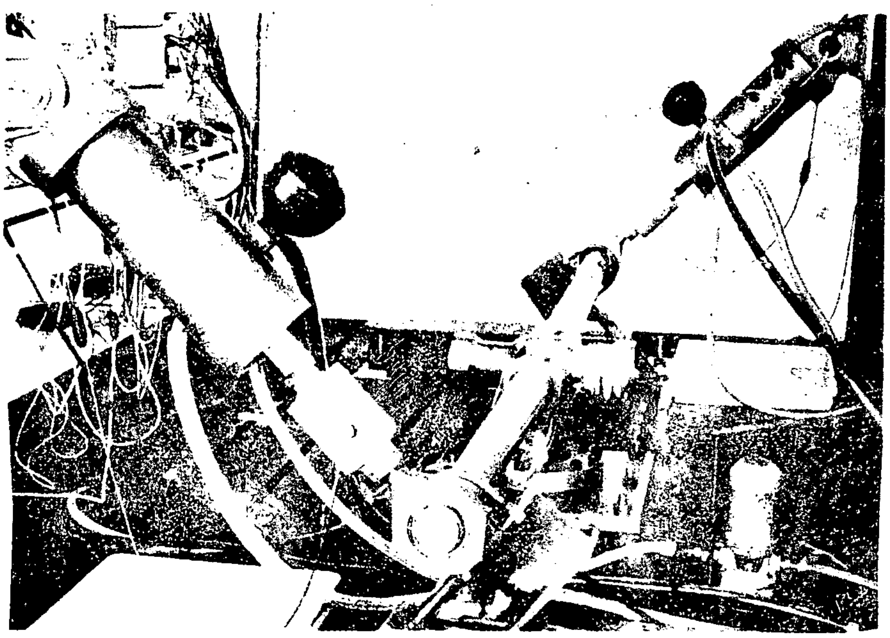


Figure 24.

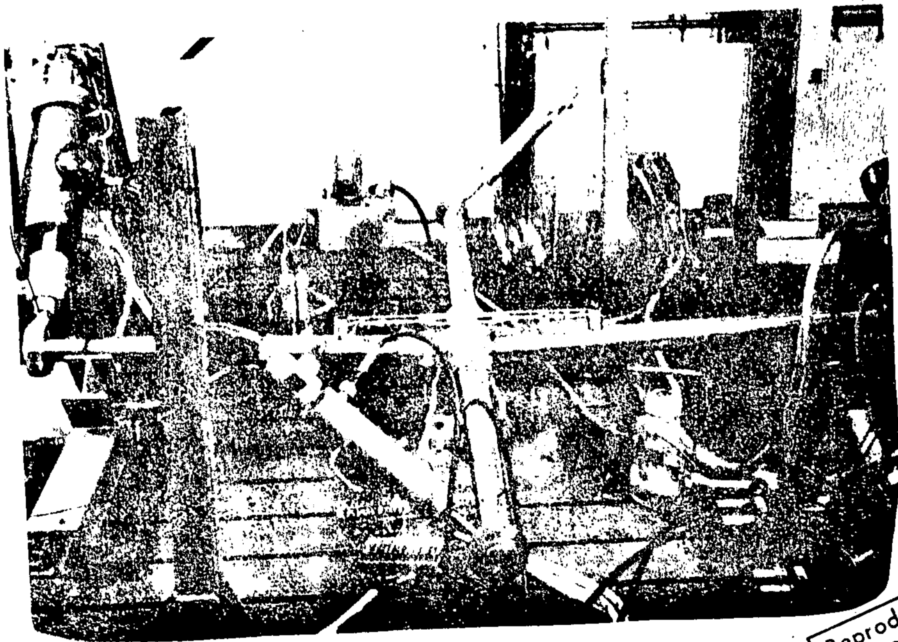


Figure 25.

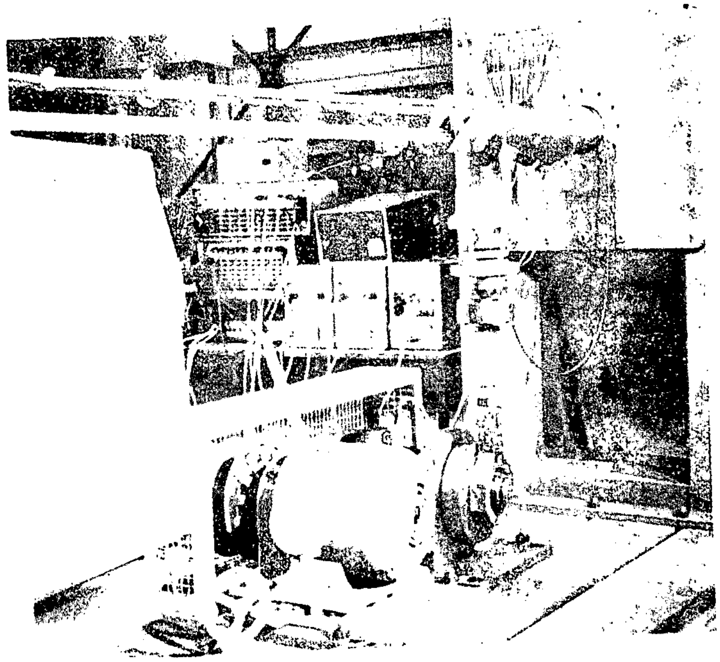


Figure 26a

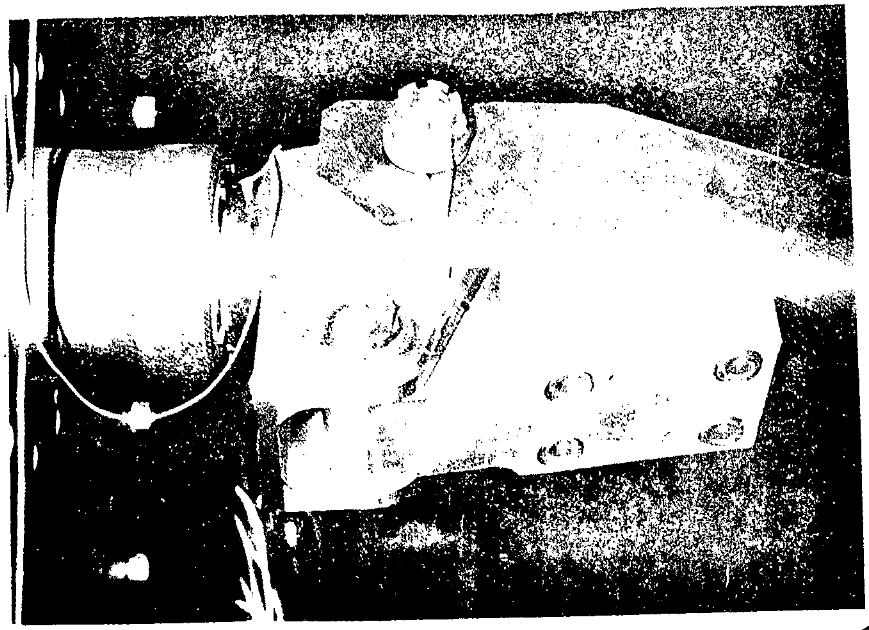


Figure 26 b

/116

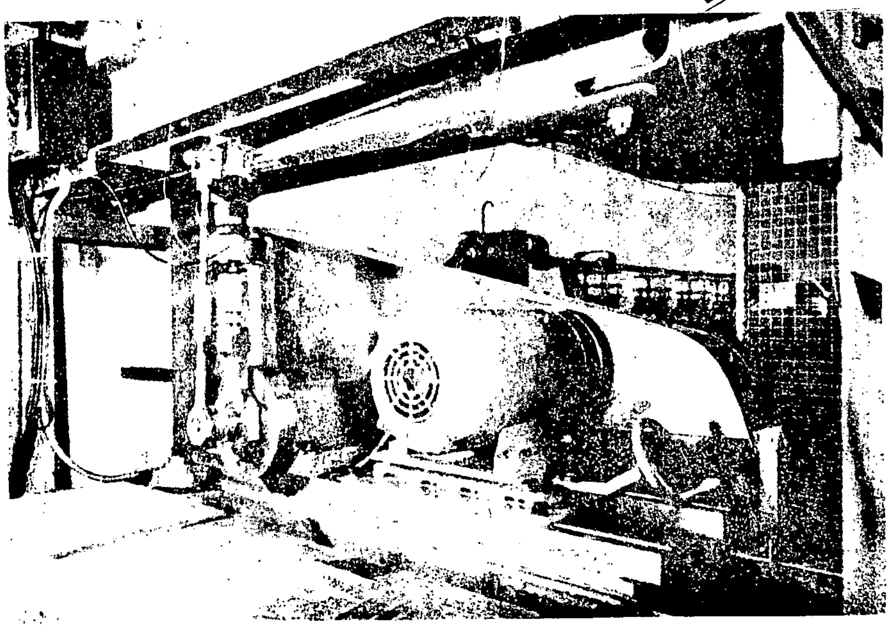


Figure 27.

The dynamic loading takes place in the two machines produced by us by means of eccentrics and an operating rod, application of the longitudinal load being by cable and hydraulic cylinder. A second eccentric comes into play in the second machine to produce the rotational movement; this second eccentric is attached to the first eccentric and its phase can be immediately adapted to the phase of the first eccentric.

Tests with the rotor mast and the flange attachment between the mast and the hub of the BO 105 are shown in Figures 28-31.

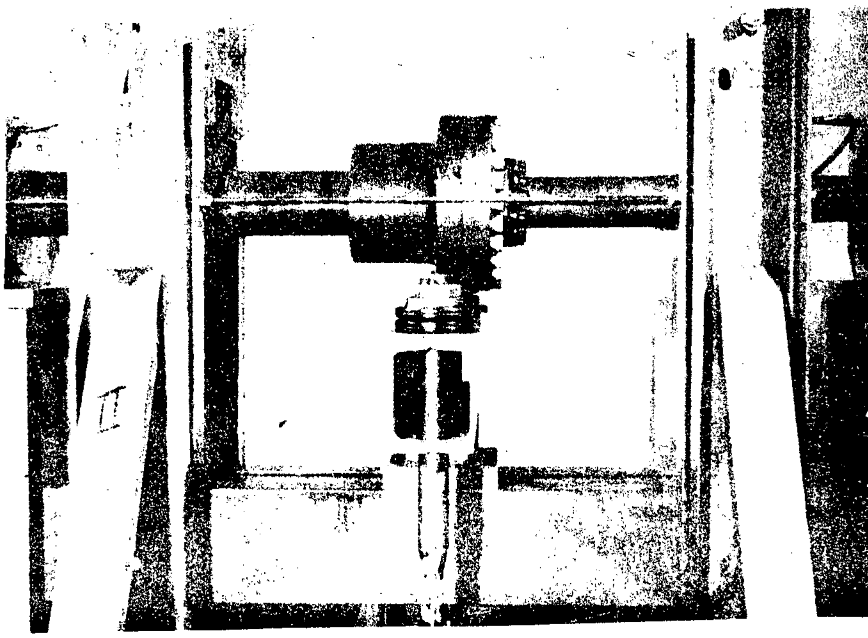


Figure 28.

Here we used machines built by ourselves with 4 pivot bearings. A bending /117
load, functioning as a rotary bending on the revolving specimen, is applied by way of the inner bearing by using a loading bridge.

The mast or the mast mock-up with the original flange is flanged together with a piece of the original rotor head. The mast is supported on the real bearing sites. The rotor head piece is held and supported by a clamping ring, a large auxiliary flange, and a comparatively thick auxiliary shaft (Figure 29).

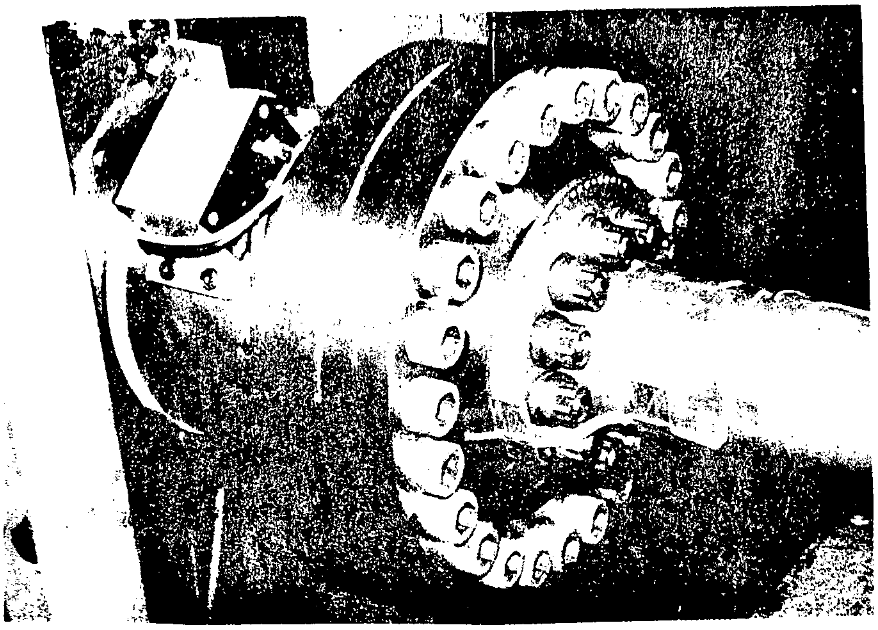


Figure 29.

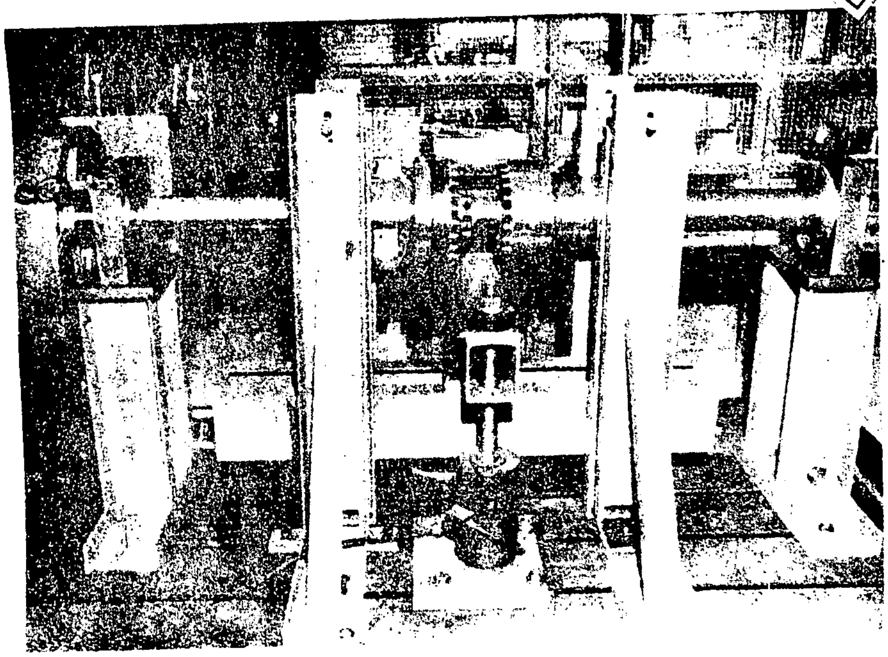


Figure 30.

Special research was fitted to the flange attachement. Here the mast was replaced by a mock-up with the original flange (Figures 30 - 31). /118

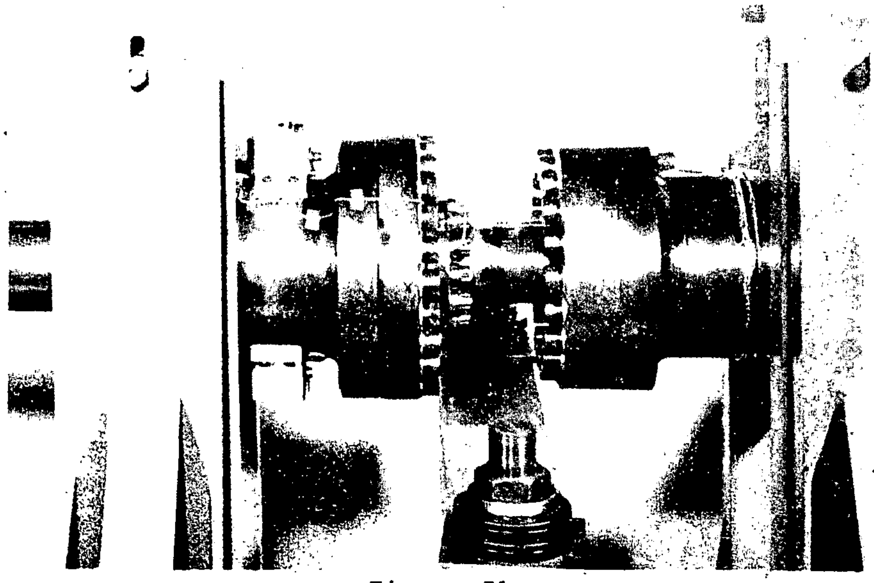


Figure 31.

Other tests concern research on the tail rotor shaft and coupling (Figures 32 and 33). Two original shafts with the original flanges, couplings and bearing sites are pressed against each other in a brace testing stand produced by us.

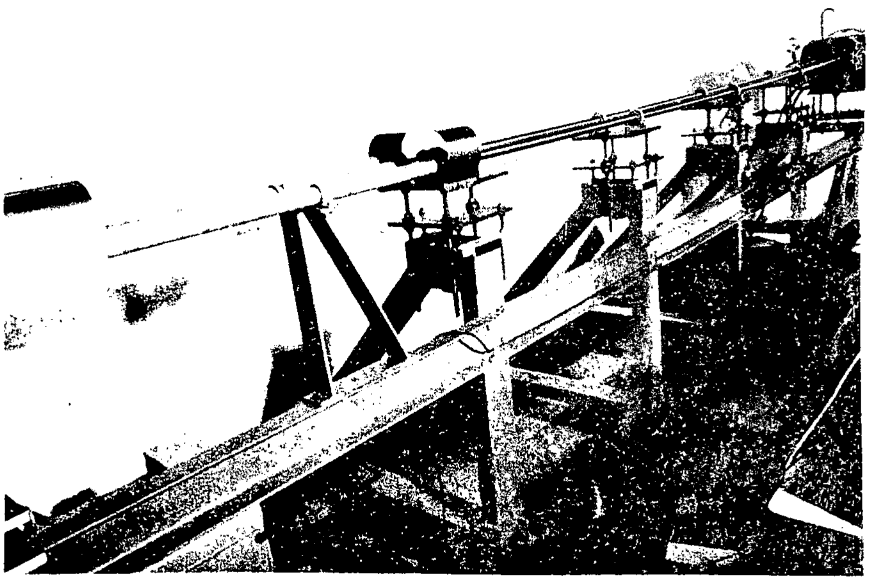


Figure 32

In addition the shafts are disconnected in the bending direction, axial pressure is applied, and the individual bearings are somewhat torsionally mounted. In this way several loading cases are superimposed in one multistage program. A special, shorter test stand with short shaft pieces (Figure 33) is used for more exact research on the couplings. /119

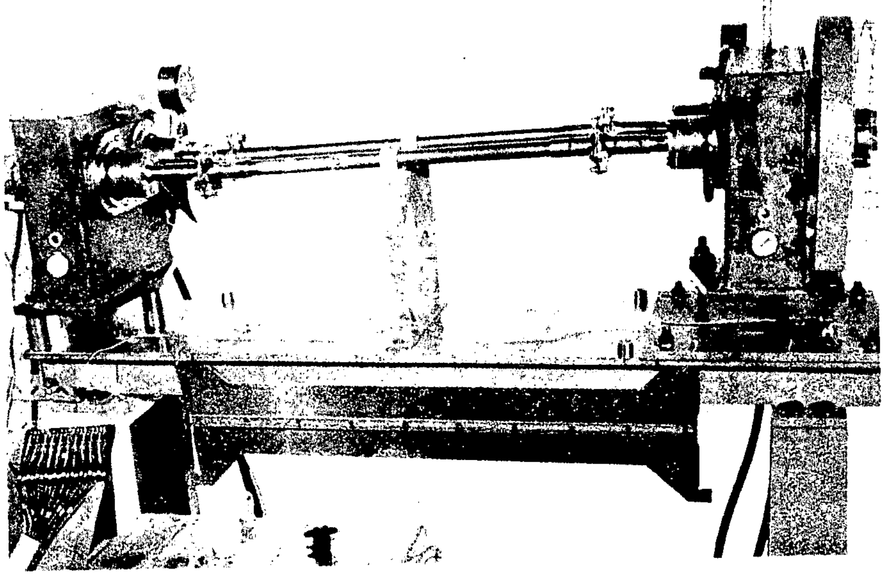


Figure 33.

Exaustive research is given to control (Figures 34 and 35).

In a testing device (Figure 34) the exact execution of the BO 105 control was simulated. The original steering rods, pedals, gears, eye heads, swash plate, and especially the hydraulic servomotors were built into the assembly. Spring boosters with matched spring characteristics, adjustable in loading, produced simulation of air forces above the blade control rods.

An electric motor was used to drive the rotating part of the swash plate. /120
By inclining the swash plate, changing forces could be applied cyclically with the rotation lifting and lowering the swash plate could apply constant forces with rotation, and manipulation of the control pedal (pitch and throttle) by means of a mechanical sine wave generator could also superimpose operating forces. In this way various cases of loading were simulated in the multistage programs, and the operating behavior and frequency curves could be determined in long duration tests.

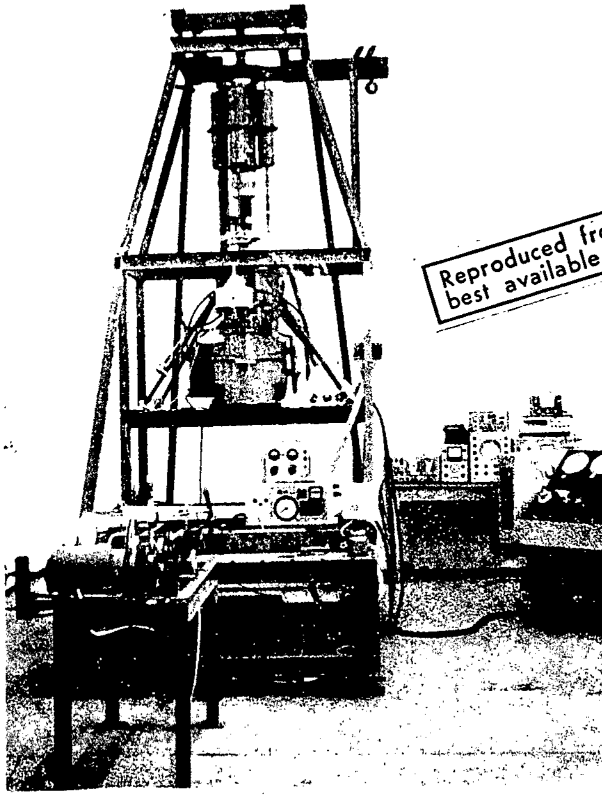


Figure 34.

Forces, control paths, deformations, stresses and bearing clearances were produced as measured variables during the tests. Hydraulics presented a special point of research in connection with the test apparatus. This test stand has already been of very great use in developing functional servomotors. In a separate test stand (Figure 35) the components taking greater stresses (swash plate, compound pedal gears, rotating control rods, booster rods) were subjected to a long term test with increased loads.

Lastly let us mention dynamic tests with a fracture segment of the BO 105 (Figures 36-38). The segment is attached to a stress area in the landing gear fittings. /121

A stationary and dynamic loading, corresponding in operation to the air and inertial forces on the main rotor, are applied to the gear mast through a hydraulic cylinder (Figure 36).

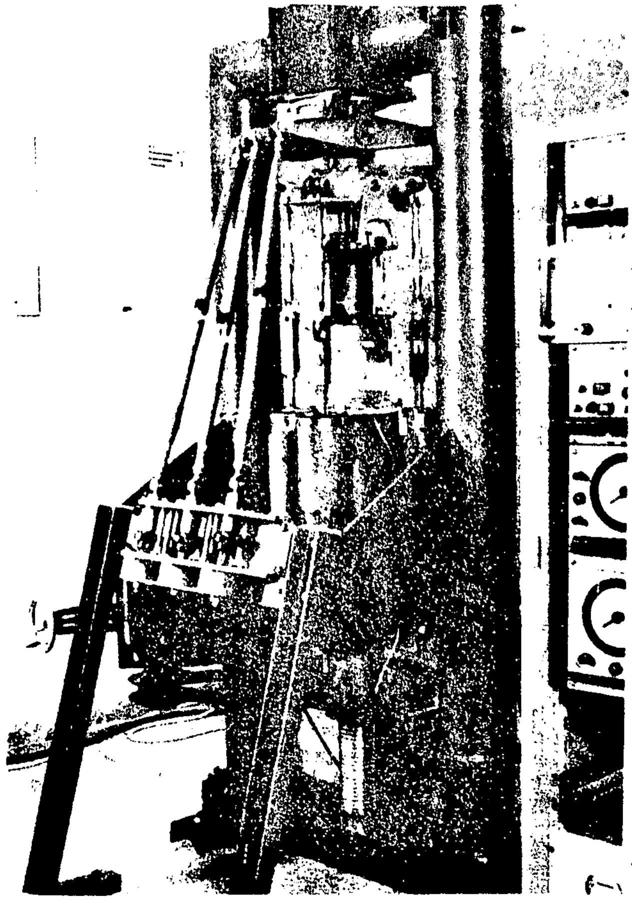


Figure 35.

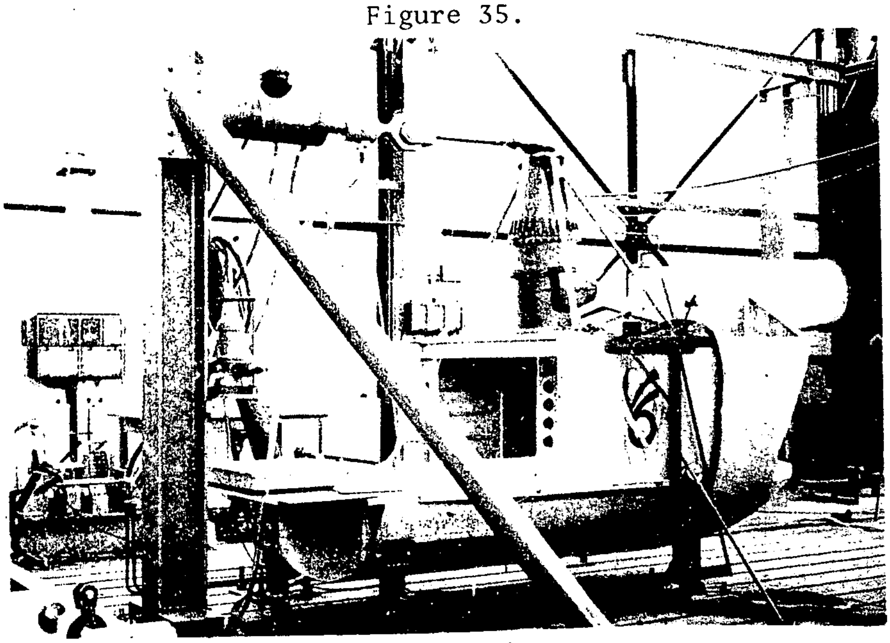


Figure 36.

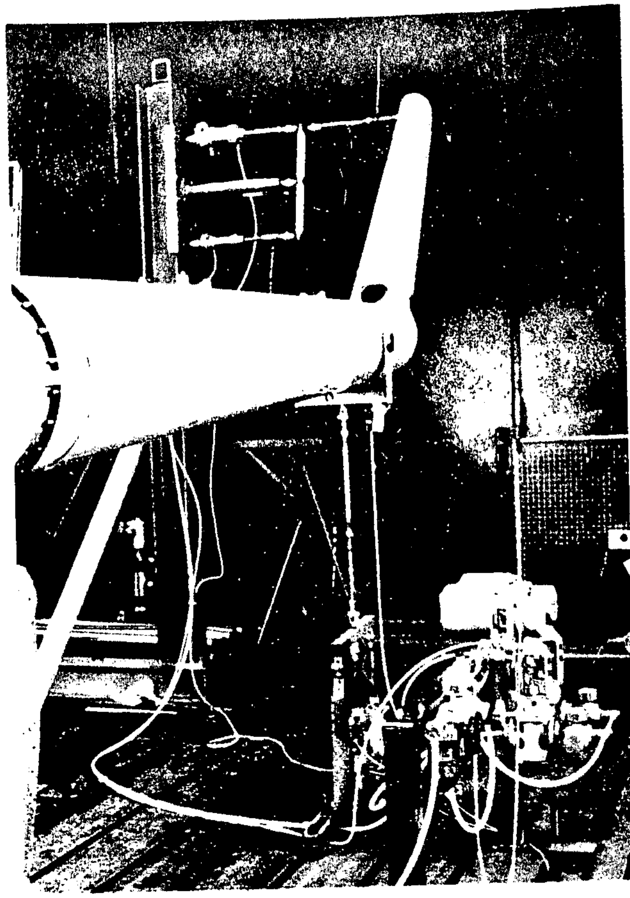


Figure 37.

In tests of the same segment on the tail boom, loading was achieved with 2 pneumatic cylinders which simulate the air forces on the horizontal stabilizers and on the tail rotor thrust (Figures 37 and 38).

With the help of these tests the weak spots in the segment could be pointed out, along with an idea of their reliability; this knowledge makes eventual improvement possible or later controls easier. /122

4. Final Considerations

In the previous section a survey of the essential tests connected with the development of the BP 105 (Figure 39) was given as an example of a testing campaign, such as can be applied in a similar form to helicopter development in general.

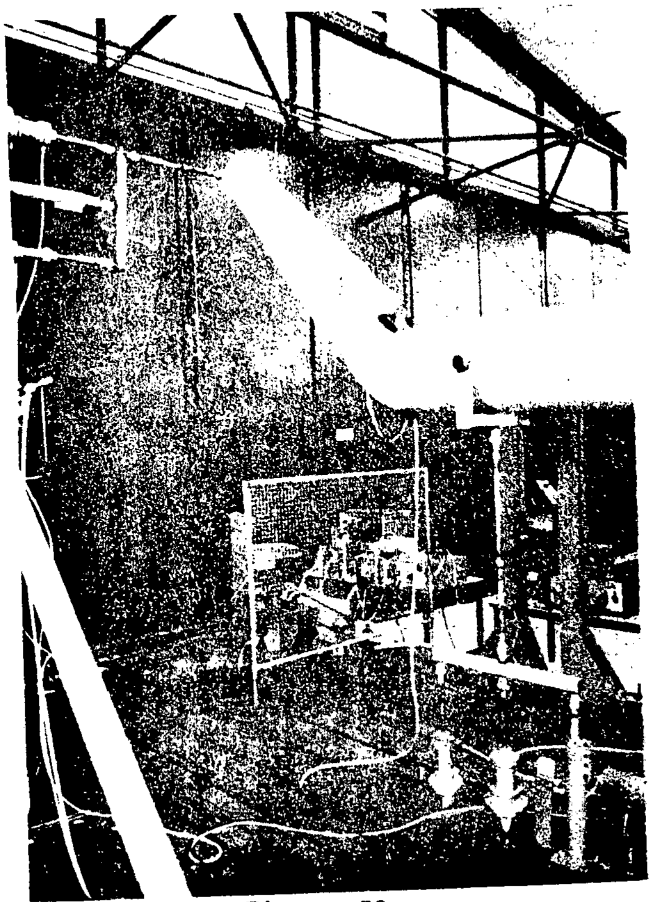


Figure 38.

/123

Figure 39.

Not all tests could be shown; rather only a selection representing characteristic tests was presented and explained for the various kinds of tests.

Translated for the National Aeronautics and Space Administration under contract No. NASw-2037 by Techtran Corporation, P. O. Box 729, Glen Burnie, Maryland 21061, Translator: Lawrence W. Murphy, Ph.D.